

# Clinical Classification of Cardiac Deaths

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**SUMMARY** One hundred forty-two deaths among 743 men ages 50–65 years who had been examined and followed 5–10 years were investigated and classified on the basis of clinical information from medical and non-medical observers, ECGs and autopsies. A classification based on the condition of the circulation immediately before death appears to be most relevant to studies of sudden death.

In 58% of the cases, the subject collapsed abruptly and his pulse ceased without prior circulatory collapse (arrhythmic death); in 42%, the pulse ceased only after the peripheral circulation had collapsed (deaths in circulatory failure). Thirty-three percent of arrhythmic deaths and 10% of deaths in circulatory failure occurred in a setting of clinical evidence of acute ischemic heart disease ( $p < 0.005$ ). Forty-five percent of arrhythmic deaths were preceded by chronic congestive heart failure without circulatory collapse. Ninety-three percent of final illnesses that lasted less than 1 hour ended in arrhythmic deaths; 74% that lasted more than 1 day ended in deaths in circulatory failure ( $p < 0.001$ ). Eighty-eight percent of deaths that occurred outside of the hospital were arrhythmic; 71% of deaths that occurred in the hospital were deaths in circulatory failure ( $p < 0.001$ ). Ninety percent of deaths in which the primary cause of the final illness was heart disease were arrhythmic; 86% of deaths in which the primary cause was other than heart disease were deaths in circulatory failure ( $p < 0.001$ ). Ninety-one percent of deaths precipitated by an acute cardiac event were arrhythmic; 98% precipitated by acute respiratory obstruction, hemorrhage, infection, stroke or other noncardiac events were deaths in circulatory failure ( $p < 0.001$ ).

TO INVESTIGATE clinical and epidemiologic problems relating to sudden death and other forms of death, definitions are needed that are unambiguous, relevant to medical questions, and based on criteria that can be applied in the conditions under which sudden death occurs. Since sudden death usually occurs outside of hospitals and is witnessed, if at all, by people without medical training, a classification of deaths that can be used in clinical and epidemiologic studies must be based on information that is likely to be available when deaths occur outside of hospitals. Most of the classifications of sudden death have been based on the duration of the final illness, the location of the death and its apparent cause.<sup>1–20</sup> These methods of classification may not yield similar results and they cannot always separate deaths into groups that are meaningfully related to the scientific question being investigated.

We explored the classification of the cardiac phenomena of death by investigating 142 deaths among 743 men, ages 50–65 years, who were studied intensively and followed prospectively for 5–10 years. Using the clinical data available at the time of death as well as information from prior examinations, we classified these deaths according to the condition of the circulation immediately before death, the presence or absence of evidence of acute ischemic heart disease at the time of death, the duration of the terminal acute illness, the location of death, the principal cause of the terminal acute illness and the cause of death.

## Methods

All 142 deaths during 1020 5-year observations of employed men, ages 50–65 years on admission to three prospective studies, were investigated and classified. Seventy-two deaths occurred among 687 men in two random samples designated from payroll lists; 70 deaths occurred among 333 employed men designated from medical records on the basis of criteria considered to place them at high risk for sudden death.<sup>22</sup>

Medical histories and information on smoking, drinking, medication, activities, social background and daily time budgets were obtained; physical examinations were carried out; biochemical and hematologic examinations, including determinations of blood lipids, glucose tolerance and serum uric acid, were performed; and standard PA and left lateral chest x-rays, 12-lead ECGs and 10–24-hour recordings of the ECGs were obtained.<sup>22</sup>

Information about deaths was obtained from first-hand reports of witnesses (interviews, letters, nurses' notes in hospital records), second-hand reports of witnesses (associates' reports or company reports of what witnesses said), hospital records, reports of physicians, and reports of police or rescue squads. Special arrangements were made with medical examiners in the New York metropolitan region to obtain autopsies and to facilitate obtaining autopsy reports. Information about the condition and activities of subjects immediately before their deaths was obtained from interviews with wives, other family members and associates, and from private physicians, company physicians, hospital records and our own previous examinations (table 1).

Cardiac deaths were defined as occurring when the rhythmic contractions of the ventricles ceased and did not return spontaneously. Cardiac death was considered to have occurred when the subject's pulse or other evidences of ventricular contractions were no longer detectable by observers and did not return spontaneously.

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TABLE 1. *Sources of Data*

	n	%
Deaths investigated	142	100.0
In random samples	72	50.7
In high-risk samples	70	49.3
Deaths		
Witnessed directly	110	77.5
Not witnessed directly	32	22.5
Observed within 1 hour before death	18	
Evidence of clinical condition before death	31	
Data available		
Witness reports	110	77.5
First hand	96	
Second hand	14	
Physicians' reports	82	57.7
Hospital records	95	66.9
Autopsy reports	44	31.0
Wife or other family member's report	68	47.9
Associate's report	28	19.7
Company report	83	58.4
Other reports (rescue squad, police, etc.)	8	5.6
Two or more of the above	142	100.0
Three or more of the above	135	95.1
Death certificates	123	86.8
Medical examination before death	142	100.0

Statistical comparison between arrhythmic deaths and deaths in circulatory failure were carried out by the usual chi-square test for contingency tables, using the Fisher exact test for tables with small numbers. Analyses of ordered categories were done by the chi-square test for trend in proportions.

## Results

### Classification Based Upon the Condition of the Circulation Immediately Before Death

#### Witnessed Deaths

Sixty-one of 110 witnessed deaths (55.4%) occurred abruptly without prior collapse of the circulation (table 2).

Abruptness of the death was judged by the rapidity with which the subject lost consciousness and his pulse disappeared. If a subject was seen (1) awake, alert and without apparent impairment of his mental functions, (2) active and able to maintain a standing or sitting position, or (3) sleeping normally and could be readily aroused, we assumed that his brain was being adequately perfused with oxygenated blood and that his peripheral (cerebral) circulation was intact. For men who died while under anesthesia, physicians' reports and hospital records concerning the condition of the

pulse and the blood pressure and the presence or absence of shock immediately before death were taken as the guide for classification (table 3).

Thirty-four cases showed no evidence of circulatory impairment until they collapsed and the pulse disappeared. In 18 cases, the decedent had had chronic congestive heart failure that had been treated (usually with digitalis glycoside and diuretics) and was not disabled, and there was no evidence of exacerbation of cardiac failure before collapse. In nine cases, the decedent had been chronically or subacutely disabled by cardiac failure that required a bed-chair existence, but had no evidence of acute exacerbation of cardiac failure before collapse. These deaths were classified as arrhythmic.

In 49 cases, the subject's circulation failed steadily and he lost consciousness, but some time elapsed before circulation ceased and pulse and respirations disappeared. In most cases, the circulatory failure proceeded slowly, but in some cases it proceeded rapidly. These were classified as death in circulatory failure.

Forty-one deaths in circulatory failure were attributed to failure of the peripheral circulation initiated by hemorrhage or trauma,<sup>14</sup> infection,<sup>16</sup> stroke,<sup>7</sup> and acute obstructive respiratory failure.<sup>4</sup> Eight deaths in circulatory failure were primarily attributed to failure of the myocardium. Five of these were caused by acute myocardial infarctions. Three patients in circulatory failure died rapidly. One of these deaths was attributed to pulmonary embolism and occurred "within a few minutes," and two deaths were caused by automobile accidents.

#### Unwitnessed Deaths

Thirty-two deaths were not witnessed directly or the final moments could not be adequately described. These were classified into "probable" categories, based upon the circumstances of the deaths, the location and position of the body when it was found, and the condition of the subject as described by those who had seen him last before he died. Most of the decedents had been observed within a few minutes before they were found dead, but in some cases more than 24 hours had elapsed (table 4).

The evidence indicated that 23 of these deaths were abrupt. Eleven cases had no previous evidence of circulatory failure and the circumstances of the death suggested that none had occurred before the loss of consciousness. Three unwitnessed deaths occurred in men who had chronic congestive heart failure that had not been disabling, and apparently had not increased in severity before they died abruptly. Seven unwitnessed deaths occurred in men who had disabling chronic congestive heart failure without evidence of an increase in heart failure until they died abruptly. Ten unwitnessed deaths were probably preceded by circulatory collapse. One death was unclassifiable.

#### Effects of Therapeutic Intervention

Therapeutic interventions prevented death in two cases, changed the mode of death in two cases, and

TABLE 2. *Classification of Cardiac Deaths Based on the Condition of the Circulation Immediately Before Death*

Categories	Deaths in 72 random samples (%)	Total deaths (n = 142) (%)
I. Arrhythmic deaths (abrupt loss of consciousness and disappearance of pulse without prior collapse of the circulation)	55.5	57.7
1. Not preceded by impairment of circulation	29.1	31.7
Witnessed directly	25.0	23.9
Not witnessed directly	4.2	7.7
2. Preceded by chronic congestive heart failure, not disabling	13.9	14.8
Witnessed directly	13.9	12.7
Not witnessed directly	0.0	2.1
3. Preceded by chronic congestive heart failure, disabling	12.5	11.3
Witnessed directly	8.3	6.3
Not witnessed directly	4.2	4.9
II. Deaths in circulatory failure (gradual circulatory failure and collapse of circulation before disappearance of pulse)	43.1	41.5
1. Primarily caused by failure of peripheral circulation	41.2	35.9
Witnessed directly	33.3	28.9
Not witnessed directly	8.3	7.0
2. Primarily caused by myocardial failure	1.4	5.6
Witnessed directly	1.4	5.6
Not witnessed directly	0.0	0.0
III. Deaths not classifiable	1.4	0.7

precipitated death in four cases. Three men with severe acute obstructive respiratory failure died abruptly during attempted tracheal intubation. One death in circulatory failure was precipitated by an aortocoronary bypass operation.

In keeping with the definition of cardiac death as occurring when the rhythmic contractions of the ventricles ceased and did not return spontaneously, the deaths of men who had abrupt episodes of ventricular arrhythmia from which they were transiently or permanently resuscitated were considered to be arrhythmic deaths. The three abrupt deaths during tracheal intubation were classified as arrhythmic. The postoperative death was classified as death in circulatory collapse.

#### *Electrocardiographic Findings at the Time of Death*

In one case, the ECG of a man was being recorded when he died;<sup>23</sup> in 14 cases the ECG was being monitored; and in 14 cases, electrocardiographic tracings were obtained soon after the subject collapsed (table 3). In 27 cases, a ventricular arrhythmia was reported to be present at the time of death. In two cases, the nature of the arrhythmia was not reported. In no case was the electrocardiographic evidence inconsistent with the classification of the death as arrhythmic or in circulatory failure based on the observation of the subject at the time of death.

#### *Autopsy Findings*

One or more manifestations of heart disease were found at each of the 22 autopsies of men who experienced abrupt arrhythmic death (table 3). In no case was there a report of any lesion other than cardiac that might have explained the collapse and death.

Eighteen of 22 autopsies of men who died in circulatory failure revealed anatomic evidence of heart disease. In all of the cases except those with acute myocardial infarction, there was a finding of a significant probable cause of death other than heart disease.

#### *Classification in Relation to Clinical Evidence of Acute Ischemic Heart Disease at the Time of Death*

The 110 witnessed deaths could be classified relative to symptoms and signs of angina pectoris, acute coronary insufficiency or myocardial infarction at the time of death (table 5). Such evidence was present at the time of 32.8% of the arrhythmic deaths and 10.2% of the deaths in circulatory failure.

Nine of 22 autopsies of arrhythmic deaths revealed recent acute myocardial infarcts or thromboses of major coronary vessels (table 3). Seven of these had been clinically silent in the sense that the close associates of the subject had not noticed acute illness or heard complaints of symptoms before death.

Recent acute myocardial infarctions were found

TABLE 3. *Information Relating to the Mode of Death*

TABLE 3. Information relating to the mode of death					
	Arrhythmic deaths (n = 82)		Deaths in circulatory failure (n = 59)		
	n	%	n	%	
Evidence of functional level of CNS immediately before death					
1. Level of arousal					
Awake	68	82.9	0	0.0	<i>p</i> < 0.0001
Asleep	12	14.6	0	0.0	
Under anesthesia	2	2.4	3	5.4	
Comatose	0	0.0	56	94.9	
2. Activity and posture					
Active	34	41.5	0	0.0	<i>p</i> < 0.0001
Standing	5	6.1	0	0.0	
Sitting	15	13.3	0	0.0	
Lying	28	34.2	59	100.0	
Electrocardiographic information at time of death					
1. ECG					
Recorded	1	1.2	0	0.0	
Monitored	4	4.8	10	16.9	
ECG	13	15.8	1	1.6	
Total	18	22.0	11	18.6	
2. Terminal arrhythmia					
Ventricular fibrillation	15	18.3	3	5.1	<i>p</i> < 0.002
Asystole or "arrest"	3	3.6	6	10.2	
Not reported	0	0.0	2	3.4	
Autopsy information					
1. Autopsy performed					
At New York Hospital	5	6.1	1	1.7	
Elsewhere	17	20.7	21	35.6	
Total	22	26.8	22	37.3	
2. Pathologic findings					
Occlusion of one or more major coronary vessels	20	90.1	7	31.8	<i>p</i> < 0.0002
Acute myocardial infarct or coronary occlusion	9	40.9	2	9.1	<i>p</i> < 0.034
Weight of heart ≥ 350 gm	20	90.1	12	54.5	<i>p</i> < 0.016
Significant valvular disease	1	4.5	1	4.5	NS
No anatomic evidence of heart disease	1	4.5	4	18.2	NS
Probable precipitating cause of death other than heart disease	0	0	17	77.3	<i>p</i> < 0.0001

TABLE 4. Deaths by Category in Relation to Duration of the Terminal Acute Illness

Duration of terminal acute illness	Arrhythmic deaths (n = 82)		Deaths in circulatory failure (n = 59)		All deaths (n = 142)	
	n	%	n	%	n	%
Less than 5 minutes	37	45.1	0	0.0	37	26.1
> 5 minutes, < 1 hour	16	19.5	4	6.8	*21	14.8
> 1 hour, < 4 hours	7	8.5	1	1.7	8	5.6
> 4 hours, < 24 hours	5	6.1	6	10.2	11	7.7
> 24 hours, < 1 week	8	9.7	13	22.0	21	14.8
> 1 week	9	11.0	35	59.3	44	31.0
<i>p</i> < 0.0001						

\*Includes one unclassifiable death.

(Maximum duration of terminal acute illness of subjects whose deaths were not directly witnessed includes time from onset of illness or from time last seen alive to time body was found)

at autopsy in two of 22 men who died in circulatory failure. Both infarctions had been recognized clinically.

#### Classification by the Duration of the Terminal Acute Illness

The duration of the terminal acute illness was considered to have been the duration of the symptoms and signs of acute illness or of the acute exacerbation of chronic illness that proceeded uninterrupted to the disability and death of the subject.

Thirty-five of 37 deaths in which the terminal acute illnesses lasted less than 5 minutes (table 4) were abrupt deaths and were not accompanied by symptoms of acute illness. They had the characteristics of deaths that have been called "instantaneous."<sup>9</sup> Two deaths that occurred within 5 minutes were accompanied by evidence of severe acute anginal pain. Except for angina, these also had the characteristics of instantaneous deaths.

The 58 men with terminal acute illnesses that lasted less than 1 hour (40.8% of all deaths) met the most frequently used criterion for sudden death.<sup>1-20</sup> Fifty-three (91.3%) of these were arrhythmic deaths. The four deaths in circulatory failure included two caused

by automobile accidents, one caused by acute congestive heart failure, and one caused by a pulmonary embolism. One death that occurred within 1 hour was not classifiable.

Half of all terminal acute illnesses lasted less than 1 day. Most of these deaths met the criteria for sudden death suggested by Paul and Schatz<sup>2</sup> and those recommended by the World Health Organization.<sup>3</sup> They included the 57 deaths described above. Sixty-five of the 77 deaths (84.4%) were arrhythmic deaths. Eleven were deaths in circulatory failure. Five of the 11 men in circulatory failure died with clinical evidence of acute myocardial infarctions, and all died in shock within 1 day.

Almost half of all terminal acute illnesses lasted more than 1 day. Forty-eight of 65 were deaths in circulatory failure from causes other than heart disease, but 17 (26.2%) were abrupt arrhythmic deaths that terminated acute illnesses primarily caused by heart disease lasting longer than 1 day.

#### Classification by Location of the Death

Sixty-nine deaths (48.6%) occurred outside of hospitals (table 6). Sixty of these were arrhythmic deaths and occurred in men who had not been disabled

TABLE 5. Deaths Witnessed Directly: Clinical Evidence of Acute Ischemic Heart Disease at Time of Death

	Deaths	Evidence of acute ischemic heart disease	
		n	%
I. Arrhythmic deaths	61	20	32.8
1. Not preceded by any impairment of circulation	34	14	41.2
2. Preceded by chronic congestive heart failure, not disabling	18	3	16.7
3. Preceded by chronic congestive heart failure, disabling	9	3	33.3
II. Deaths in circulatory failure	49	5	10.2
1. Caused by failure of peripheral circulation	41	0	0.0
2. Caused by myocardial failure	8	5	62.5
All directly witnessed deaths	110	25	22.7

*p* < 0.019

TABLE 6. *Deaths by Category in Relation to the Location of Death*

Location of death	Arrhythmic deaths (n = 82)		Deaths in circulatory failure (n = 59)		All deaths (n = 142)	
	n	%	n	%	n	%
In hospital	21	25.6	51	86.4	*73	51.4
En route	2	2.4	1	1.7	3	2.1
At home	34	41.5	5	8.5	39	27.5
As a patient	4	4.9	5	8.5	9	6.3
Otherwise	30	36.6	0	0.0	30	21.1
At work	6	7.3	0	0.0	6	4.2
En route	7	8.5	0	0.0	7	4.9
At place of recreation	5	6.1	0	0.0	5	3.5
Elsewhere	7	8.5	2	3.4	9	6.3
<i>p</i> < 0.0001						

\*One death in hospital was unclassifiable.

before the onset of an acute illness that lasted 4 hours or less. Nine were deaths in circulatory failure. Six of these occurred in men who were receiving terminal care at home for chronic illness other than heart disease.

Twenty-one of the 72 hospital deaths were abrupt arrhythmic deaths. Twelve occurred in men with disabling heart disease, 11 of whom had terminal illnesses that lasted more than 1 day. Seven others were in men under observation or treatment for acute episodes of ischemic heart disease that had lasted for more than 4 hours.

Fifty-seven of 66 men (86.4%) who had not been disabled before their terminal acute illnesses died abruptly outside of hospitals. Twelve of 16 men (75%) who had disabling heart disease and died abruptly died in the hospital; 51 of 59 men (85.4%) who died in circulatory failure died in hospitals.

All deaths that occurred at places of recreation where people usually engage in physical activity (for example, on golf courses or in dance halls) were abrupt deaths without preceding evidence of circulatory impairment.

#### Classification by the Principal Cause of the Terminal Acute Illness

Seventy-four of 82 acute illnesses that terminated in abrupt deaths (90.2%) were attributed primarily to heart disease (table 7). Eight were primarily attributed to causes other than heart disease (pulmonary disease, cancer or other forms of cardiovascular disease); but seven of these cases had associated heart disease and five had severe hypoxia. One case that was not associated with anatomic evidence of heart disease was associated with severe hypoxia and agitation.

Eight of 60 deaths in circulatory collapse were primarily attributed to heart disease, five of which were caused by acute myocardial infarctions. Of deaths in circulatory failure, 86.7% were attributed primarily to noncardiac causes (cancer, stroke or ruptured aneurysm, degenerative diseases and trauma).

#### Classification in Terms of the Precipitating Cause of Death

The 82 men who died abruptly had an acute disturbance of the cardiac rhythm that led to ventricular arrhythmia. In 81 cases, these disturbances of rhythm appeared to be manifestations of underlying heart disease. Twenty-six cases had an acute episode of ischemic heart disease (table 8); in 55 cases (67.9%), there was no clinical evidence of acute heart disease, but there was clinical or autopsy evidence of chronic heart disease. In one case there was no chronic heart disease, but there was severe hypoxia and marked agitation, with evidence suggesting subacute and moderately severe cardiac failure.

Fifty-two of 60 deaths in circulatory failure (86.7%) were precipitated by acute conditions not related to heart disease: hemorrhage, infection, other causes of peripheral vascular failure, stroke and acute respiratory obstruction. Eight deaths in circulatory failure were precipitated by an acute condition related to

TABLE 7. *Death by Category in Relation to the Primary Cause of Terminal Acute Illness*

Primary cause of terminal illness	Arrhythmic deaths (n = 82)		Deaths in circulatory failure (n = 59)	
	n	%	n	%
Coronary heart disease	49	59.8	6	10.2
Other heart disease and combinations of heart disease	25	30.5	2	3.4
Other cardiovascular disease	2	2.4	14	23.7
Pulmonary disease	4	4.9	1	1.7
Cancer	2	2.4	26	44.0
Metabolic disease	0	0.0	0	0.0
Trauma	0	0.0	2	3.4
Other causes	0	0.0	8	13.6
<i>p</i> < 0.0001				

TABLE 8. *Deaths by Category in Relation to Precipitating Cause of Death*

Precipitating cause of death	Arrhythmic deaths (n = 82)		Deaths in circulatory failure (n = 59)	
	n	%	n	%
Acute MI or coronary occlusion	14	17.1	5	8.5
Other acute ischemic episodes	13	15.8	0	0.0
Other acute episodes of heart disease	53	64.6	3	5.1
Acute respiratory obstruction	1	1.2	6	10.2
Hemorrhage	0	0.0	12	20.3
Infection	0	0.0	17	28.8
Stroke	0	0.0	9	15.3
Other causes of cardiovascular failure	0	0.0	5	8.5
Undetermined	0	0.0	2	3.4
$p < 0.0001$				

heart disease: myocardial failure, which was attributable to acute myocardial infarction in five cases and to other heart disease in three cases.

### Discussion

Among the classifications that were examined, the classification according to the apparent condition of the circulation immediately before death appears to be the most useful for studying sudden death, because it divides the decedents into categories that are relevant to what appears to be the major mechanism of sudden death.<sup>24</sup> The evidence strongly suggests that the deaths that we called abrupt and have classified as arrhythmic were caused by the sudden occurrence of a disorder of cardiac rhythm when the pumping action of the heart, up to that moment, had been adequate to sustain the peripheral circulation. The disorder of rhythm apparently preceded the collapse of the circulation.

A classification of deaths as arrhythmic or circulatory failure cannot be entirely accurate unless the ECG is observed or recorded at the time of death. When such a classification is made on the basis of the rapidity with which cerebral function ceases and the peripheral pulses are no longer detectable, it is entirely presumptive. A classification on this basis is undoubtedly more accurate when the decedents are members of population samples of known medical and demographic characteristics, and when all have been examined medically before their deaths, as they were in these studies. The accuracy is better when the deaths are observed directly. It is even better when an ECG is taken shortly after the subject collapses and when an autopsy is obtained. However, in these studies, the additional information from these two sources was more relevant to understanding the under-

lying causes of death and the nature of the precipitating event than to classifying the death as arrhythmic or in circulatory failure. In the cases in which this information was available, the classification of witnessed deaths on the basis of the clinical observation was confirmed or supported by the electrocardiographic or autopsy findings, but it was not changed.

When the unwitnessed deaths were classified by the position and the apparent activity of the subject at the time of death, the classifications were consistent with those of the witnessed deaths. The evidence from the autopsies and from the ECGs made at the time of collapse or shortly thereafter did not contradict the classification in any case; but this evidence did allow us to classify some cases that otherwise would not have been classifiable.

There are probably errors of classification, even though none have been identified among the 141 deaths that we classified. An estimate, based upon the proportion of cases in which the observational data were least complete or somewhat ambiguous, suggests that the number of misclassifications is not greater than 5%, and if present, primarily occurred among the unwitnessed deaths.

A terminal acute illness of short duration was a good indicator of the occurrence of an arrhythmic death. Fifty-three of 58 men (91.3%) whose terminal acute illnesses lasted less than 1 hour had an arrhythmic death. A longer terminal acute illness was not necessarily an indication of a death in circulatory failure. Seventeen of 65 men (26.1%) whose final acute illnesses lasted more than 1 day had arrhythmic deaths. Almost one-third of the deaths that occurred in hospitals were sudden arrhythmic deaths. Many were unexpected.

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